Surface Treatment Methods To Improve The Adhesive Cementation Of Zirconia Based Ceramic

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Abstract:

Modern dentistry requires increasingly esthetic, tough ,and biocompatible restorative materials. The application of ceramic materials in fixed dental prostheses and restorations have become increasingly popular because they mimic natural tooth color in comparison to other restorative materials. Zirconium oxide (zirconia) demonstrates superior mechanical properties, chemical stability, and biocompatibility compared to other ceramic materials being applied in framework structures

Etching with hydrofluoric acid and silanization are effective methods to bond silica-based ceramic materials). However, etching with hydrofluoric acid or silanization have no positive effect on the properties of zirconia because of their resistance to acids and absence of silicon oxide.

Researchers have therefore proposed a number of surface conditioning methods to
achieve reliable and durable bonding to zirconia over the past two decades. The representative materials and methods are airborne-particle abrasion with aluminum
oxide particles (alumina blasting) airborne-particle abrasion with aluminum oxide modified with silica (silica-coating) followed by silanization, primers
containing 10-methacryloyloxydecyl dihydrogen phosphate (MDP) luting agents containing MDP, selective infiltration-etching, and coating with nano-structured alumina

The purpose of the current study was to evaluate the effect of mechanochemical surface preparation on the bond strength of a self-polymerizing acrylic resin bonded to zirconia.

Introduction:

Over the last decade, it has been observed that there is an increasing interest in the ceramic materials in dentistry. Esthetically these materials are preferred alternatives to the traditional materials in order to meet the patients' demands for improved esthetics. (1)

In dentistry, ceramics represents one of the four major classes of materials used for the reconstruction of decayed, damaged or missing teeth. Other three classes are metals, polymers, and composites. (1)

The word Ceramic is derived from the Greek word "keramos", which literally means 'burnt stuff', but which has come to mean more specifically a material produced by burning or firing. (1)

The American Ceramic Society had defined ceramics as inorganic, non-metallic materials, which are typically crystalline in nature, displaying a regular periodic arrangement of the component atoms, and may exhibit ionic or covalent bonding. compounds of oxygen with one or more metallic or semi-metallic elements like aluminum, calcium, lithium, magnesium, phosphorus, potassium, silicon, sodium, zirconium & titanium. (2.6.7)

Dental ceramics can be classified in several possible ways according to their: (1) use or indications (2) composition (3) processing (4) firing temperature (5) microstructure (6) translucency (7) fracture resistance(8) abrasiveness. (2)

At a microstructural level, we can define ceramics by the nature of their composition of glass–crystalline ratio (2)

The mechanical and optical properties of dental ceramics mainly depend on the nature and the amount of crystalline phase present. More the glassy phase more the translucency of ceramics; however, it weakens the structure by decreasing the resistance to crack propagation. On the other hand, more the crystalline phase better will be the mechanical properties which in turn would alter the aesthetics. (7)

Recent developments in ceramic materials science for dental applications have led to a class of high fracture strength materials represented by alumina (Al_2O_3) and zirconia-based ceramics (ZrO_2) that potentially enable long-term durability.(8)

The increase of mechanical properties by (ZrO_2) addition is accompanied by a reduction in the glassy matrix and (Si) content resulting in acid-resistant ceramics.(9)

Oxide ceramic that does not comprise silicon dioxide (SiO_2) phase in its microstructure. Since it is challenging to create durable adhesion between resin cements and this kind of nonetchable ceramic, efforts have been made to develop innovative surface conditioning methods over the years.(10)

The aim of this study was to discuss the surface treatment methods for increasing adhesion capability of (ZrO_2) by means of reviewing the literature, establishing a protocol for clinical procedures.

Review:

The clinical success of ceramic restorations depends on the cementation process. Adhesive cementation to (ZrO_2)ceramics is desirable since it improves retention, marginal adaptation, and fracture resistance ,reduces the possibility of recurrent decay, and enables more conservative cavity preparations. Different methods to promote the adequate adhesion between the resin cement and (ZrO_2) have been proposed: use of a phosphate-modified monomer (MDP) in resin cement, laboratory or chairside air-abrasion with 110 and 30 μm Si coated aluminum particles, the use of zirconate coupler primers, tetraethoxysilane flame-treat device usage, the use of organofunctional silanes, laser irradiation, the Si vapor phase deposition method, and the selective infiltration etching procedure.

The following sections are based on the types of surface treatment methods for (ZrO_2). Treatments were divided into chemical surface treatments, mechanical surface treatments, and alternative treatments.

Chemical surface treatments:

i. ***Hydrofluoric Acid Etching***: The most common surface treatment method for adhesive cement to ceramic restorations is based either on micromechanical bond obtained with HF etching, particles sandblasting or on chemical bond, obtained by the application of a silane coupling agent .HF removes the glassy matrix of glass ceramics creating a high surface energy substrate with microporosities for the penetration and polymerization of resin composites, that is, enabling a micromechanical interlocking .However, HF etching does not produce any change in arithmetic roughness (Ra) of (ZrO_2). The negligible effect of the HF on the (ZrO_2) surface occurs due to the absence of glassy matrix, resulting in low bond strength values.

ii. ***Functional Monomers***: Special functional monomers have been used to improve the adhesion to (ZrO_2). These materials present a chemical affinity for metal oxides and can be included both in resin cement and adhesives or applied directly over the ceramic surface.

-Phosphate ester monomers, such as 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP), chemically react with (ZrO_2), promoting a water-resistant bond to densely sintered zirconia ceramics .

-A phosphonic acid monomer, 6-methacryloyloxyhexyl phosphonoacetate (6-MHPA), showed some form of chemical bonding to zirconia surface ,but there is no data available regarding the effect of 6-MHPA on the resin bond strength to zirconia ceramics after severe aging conditions .

The surface treatment with primers containing functional monomers such as MDP or other phosphoric acid acrylate monomer are often recommended to improve the bonding to (ZrO_2). Since results are not always significant, the combination of primers and air-abrasion methods tend to produce better bond strength, especially in long term.

The use of new zirconia primers (a mixture of organophosphate and carboxylic acid monomers) or a phosphonic acid monomer (6-MHPA) has been tested showing good immediate results.

iii. ***Silane Coupling Agents***:

Silane coupling agents or more precisely trialkoxysilanes are hybrid inorganic-organic bifunctional molecules that are able to create a siloxane network with the hydroxyl (OH) of the (Si) in the ceramic surface and copolymerize with the resin matrix of composites also, silanes lower the surface tension of a substrate wet it, and make its surface energy higher .Thus a hydrophobic matrix (resin composite) can adhere to hydrophilic surfaces, such as silica, glass, and glass ceramics. Different types of silanes have been studied, but none of them were able to show high effectiveness in surfaces with absent or reduced (Si) content as the surface of (ZrO_2).In addition, siloxane bonds may be sensitive to hydrolytic degradation, affecting the stability of the adhesive interface .

Mechanical Surface Treatments:

i. ***Air-Abrasion with Aluminum Oxide Particles:***

Air-abrasion with aluminum oxide particles (Al_2O_3) has been studied since the nineties and its effectiveness is closely related to the sandblasted ceramic surface and the air abrasion method.

Since greater roughness was produced over different (ZrO_2) based materials, the air-abrasion method must take this fact into consideration. In-Ceram Zirconia should not be classified as pure zirconia ceramics since it is composed of 63% of alumina, 32% of zirconia, and 4% of glass matrix. In addition, alumina is less ductile than zirconia, with larger grains and higher surface hardness, which makes air abrasion more effective.

When it comes to abrasion with Al2O3, a wide range of particle size, pressure, distance from ceramic surface, working time, and impact angle have been studied. These differences can help explain contradictory results. Although studies consider the previous factors important , the type of the (ZrO2) ceramics may be mandatory. On a yttriumstabilized tetragonal zirconia (Y-TZP) material, the use of greater particle size (from $50\mu m$ to $150\mu m$) results in a rougher surface but no significant alteration in bond strength

ii. ***Si Deposition Methods***

These systems are based on the use of 110 µm(Rocatec) or 30 µm (CoJet) Si-coated alumina particles that are blasted onto the ceramic surface. Sandblasted ceramics acquires a reactive Si-rich outer surface prone to silanization and the following AC with suitable resin composites. Its use requires silane application before cementation .
The tribochemical Si-coating on ceramic surfaces increases
the bond strength of resin cement to glass-infiltrated ZrO2 or Y-TZPUsually, 2.5–2.8-bar air-abrasion pressures are used ; however, higher pressure results in higher bond strength with CoJet . In spite of that,some studies still show similar shear bond strength with and without Si-coating by air-abrasion methods Si deposition by air-abrasionmight produce a more silane

reactive surface , but it also tends to produce a surface
with lower roughness and consequently lower possibility of
mechanical interlocking with resin cement . Some
authors do not show lower roughness , but considering
this might be a true observation; the enabled chemical
interaction to resin cement or coupling agents would justify
its use .

6. Alternative Treatments

Different alternative methods to treat ZrO_2 surfaces have
been proposed and evaluated in order to produce a reliable
adhesion, especially in long term. A large range of mechanical,
chemical, or both approaches have been tried to modify
the ZrO_2 surface to increase the surface bond area, surface energy, or
wettability .

Plasma spraying (hexamethyldisiloxane) using a reactor
(Plasma Electronic, Germany), proposed in a previous study,increased
the bond strength of resin cement to ZrO_2.
The authors related that plasma is a partially ionized gas
containing ions, electrons, atoms, and neutral species. However,
the mechanism of surface modification and rise of the
bond strength remain unclear, and the authors suggested that
the improvement in bond strength might be explained by
covalent bonds .

Some studies have suggested the use of erbium-doped
yttrium aluminum garnet (Er:YAG) or CO_2 laser to enhance
the bond strength to resin cement ; therefore, the effect of laser on the
ZrO_2 could be tested with the same aim.
Laser application removed particles by microexplosions
and by vaporization, a process called ablation.However, bond
strength results indicated that the effect of laser irradiation
is contradictory. While some studies concluded that lasers
are not effective to improve the bond strength between ZrO_2

and resin cement , recent research shows the improvement of adhesion after CO_2 laser application in comparison to conventional STMand indicates this technique as an alternative method for bonding to ZrO_2 surfaces.

selective infiltration etching (SIE) and uses principles of heat-induced maturation and grain boundary diffusion to transform the relatively smooth nonretentive surface of Y-TZP into a highly retentive surface. A low temperature molting glass is applied on selected ZrO_2 surfaces and submitted to a heat-induced infiltration process,determining zirconia crystal rearrangements. After that, the glass is removed with a 5% hydrofluoric acid solution bath,

leaving intergrain nanoporosities where low-viscosity resin materials may flow and interlock after polymerization .

This method was tested in association withMDP-based resin cement, providing high and durable bond strength ,and with previous application of zirconia primers, providing increased initial bond strength but not a stable bondwith artificial aging .

Irrespective of the possibility of producing a rough surface with air-abrasion or SIE, thesemethods still do not completely assure better or durable bond strength, as it could be seen. To overcome this issue, it is clear that micromechanical plus chemical adhesion strategies should be used.

References

(1) American Journal of Materials Engineering and Technology

(2) Anusavice KJ, *Phillip's Science of Dental Materials*, Elsevier, A division of Reed Elsevier India Pvt Ltd, New Delhi, India, 2010, 11th Edition, 655-720

(3) Hämmerle C, Sailer I, Thoma A, Hälg G, Suter A, and Ramel C, Dental Ceramics: Essential Aspects for Clinical Practice, Quintessence, Surrey, 2008

(4) Ho GW, Matinlinna JP, Insights on porcelain as a dental material. Part I: ceramic material types in dentistry, *Silicon*, 3(3), 109-15, July 2011.

(5) Lung CYK, Matinlinna JP, Aspects of silane coupling agents and surface conditioning in dentistry: An overview, *Dent Mater*, 28(5), 467-77, May 2012

(6) Sukumaran VG, Bharadwaj N, Ceramics in Dental Applications, Trends Biomater. Artif. Organs, 20(1), 7-11, Jan 2006

(7) Rama Krishna Alla, *Dental Materials Science*, Jaypee Brothers Medical Publishers Pvt Limited, New Delhi, India, 2013, 1st Edition, 333-354.

(8) J. R. Piascik, E. J. Swift, J. Y. Thompson, S. Grego, and B. R. Stoner, "Surface modification for enhanced silanation of zirconia ceramics," DentalMaterials, vol. 25, no. 9, pp. 1116–1121, 2009.

(9) K. Takeuchi, A. Fujishima, A. Manabe et al., "Combination treatment of tribochemical treatment and phosphoric acid ester monomer of zirconia ceramics enhances the bonding durability of resin-based luting cements," DentalMaterials Journal, vol. 29‹ no. 3, pp. 316–323, 2010.

[10] R. M. Foxton, A. N. Cavalcanti, M. Nakajima et al., "Durability of resin cement bond to aluminium oxide and zirconia ceramics after air abrasion and laser treatment," *Journal of Prosthodontics*, vol. 20, no. 2, pp. 84–92, 2011.

[11] M. ¨ Ozcan, C. Cura, and L. F. Valandro, "Early bond strength of two resin cements to Y-TZP ceramic using MPS or MPS/4-META silanes," *Odontology*, vol. 99, no. 1, pp. 62–67, 2011.

[12] K. Takeuchi, A. Fujishima, A. Manabe et al., "Combination treatment of tribochemical treatment and phosphoric acid ester monomer of zirconia ceramics enhances the bonding durability of resin-based luting cements," *DentalMaterials Journal*, vol. 29, no. 3, pp. 316–323, 2010.

[13] S. M. P. Torres, G. A. Borges, A. M. Spohr, A. A. D. B. Cury, S. Yadav, and J. A. Platt, "The effect of surface treatments on the micro-shear bond strength of a resin luting agent and four allceramic systems," *Operative Dentistry*, vol. 34, no. 4, pp. 399–407, 200Giannini, and G. M.Marchi, "Bond strength of resin cements to